Original Article

Variations in the Distal Attachment of the Semimembranosus Muscle: A Cadaveric Study

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Abstract

Background: The semimembranosus muscle, one of the key components of the hamstring group, plays a vital role in knee joint stability, flexion, and posteromedial support. Its distal tendon exhibits a complex pattern of insertion, typically dividing into multiple expansions that attach to the medial condyle of the tibia, the oblique popliteal ligament, the posterior capsule, and surrounding fascial structures. These expansions contribute significantly to dynamic stabilization of the knee and reinforcement of the posteromedial corner. Variations in the number, pattern, and extent of these insertions have been reported in anatomical and radiological studies, reflecting the structural diversity of this region. **Material and Methods:** This descriptive cadaveric study was conducted in the Department of Anatomy at Father Muller Medical College, Mangalore. 50 lower limbs of embalmed cadavers of unknown sex and age were included. Specimens with evidence of trauma, deformity, or prior knee surgery were excluded. Standard dissection techniques were used to expose the semimembranosus muscle and trace its distal tendon. The number, pattern, and sites of insertion were observed, documented, and photographed. Variations were classified based on their anatomical distribution, and relevant morphometric measurements were recorded. **Results:** The semimembranosus muscle demonstrated significant variability in its distal attachment. The classical triple insertion pattern was observed in 60% of specimens, comprising attachments to the medial tibial condyle, oblique popliteal ligament, and popliteal fascia. In 40% of cases, variations included additional slips to the medial meniscus, posterior capsule, and fascia of surrounding muscles. Accessory bands and differences in tendon thickness were also noted. These variations suggest a more complex functional role in knee biomechanics than traditionally described. **Conclusion:** The distal insertion of the semimembranosus muscle exhibits notable anatomical variations, which have important clinical implications in knee surgeries, ligament reconstruction, and radiological interpretation. Awareness of these variations can aid surgeons in avoiding intraoperative complications and enhance the accuracy of diagnostic imaging.

Keywords: Semimembranosus muscle, distal attachment, anatomical variation, cadaveric study, knee joint, posteromedial stability.

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Introduction

The semimembranosus muscle is a key component of the hamstring group, playing an essential role in knee flexion, internal rotation of the leg, and stabilization of the posteromedial aspect of the knee joint.[1] It originates from the ischial tuberosity and extends distally as a broad tendon that demonstrates a complex pattern of insertion. This distal tendon typically divides into multiple expansions that attach to the medial tibial condyle, posterior capsule, oblique popliteal ligament, and adjacent fascial structures.[2] These expansions not only anchor the muscle but also contribute significantly to the structural integrity of the posteromedial corner, a region essential for controlling valgus, rotational, and posterior forces acting on the knee.[3]

Anatomical and radiological studies have consistently shown that the distal attachment of the semimembranosus is highly variable, with differences observed in the number, size, and distribution of its tendinous expansions.[4] In addition to the classical insertions, accessory slips may extend to the medial meniscus, popliteal fascia, and surrounding ligamentous structures.[5] Such variations highlight the dynamic and multifaceted role of the semimembranosus in knee biomechanics. The presence of these accessory attachments may influence load transmission across the joint and contribute to variations in stability and movement patterns.[3]

From a clinical standpoint, these anatomical variations assume considerable importance. Injuries involving the semimembranosus tendon or its expansions can compromise the stability of the posteromedial corner, leading to functional impairment, chronic knee pain, and altered joint mechanics.[2] Furthermore, these variations may pose challenges during surgical interventions such as ligament reconstruction, meniscal

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repair, and arthroscopic procedures, where precise anatomical knowledge is critical to avoid inadvertent damage. In radiological practice, particularly in magnetic resonance imaging (MRI), the complex insertional anatomy of the semimembranosus may mimic pathological conditions if not accurately recognized.[4] Therefore, a thorough understanding of the variability in its distal attachment is essential for clinicians, surgeons, and radiologists to ensure accurate diagnosis and effective management.

Aims and Objectives

The present study aims to investigate the variations in the distal attachment of the semimembranosus muscle through cadaveric dissection. The objectives are to identify and document the number, pattern, and sites of insertion of the semimembranosus tendon; to classify the observed variations based on their anatomical distribution; to record any accessory expansions or atypical attachments; and to analyse their morphological characteristics. Additionally, the study seeks to correlate these anatomical findings with their potential functional and clinical significance, particularly in relation to knee joint stability, surgical interventions.

Materials and Methods

Study design: This was a descriptive, observational cadaveric study conducted to analyse the variations in the distal attachment of the semimembranosus muscle. The study was carried out in the Department of Anatomy at Father Muller Medical College using embalmed adult lower limb specimens. The design focused on detailed anatomical dissection and documentation of insertion patterns without any intervention, aiming to provide a morphological assessment of variations.

Inclusion and exclusion criteria

All well-preserved embalmed adult lower limbs available in the department were included in the study. Specimens with intact posterior knee regions suitable for dissection were considered. Lower limbs showing signs of trauma, deformity, previous surgical procedures, or pathological changes affecting the knee joint and surrounding structures were excluded to avoid distortion of normal anatomical features.

Data collection procedure: Standard dissection techniques were employed to expose the semimembranosus muscle and trace its distal tendon in the posterior aspect of the knee. Careful step-by-step dissection was performed to identify the number, pattern, and sites of insertion of the tendon and its expansions. Observations were systematically recorded, and photographic documentation was carried out for each specimen. Variations were classified based on anatomical distribution, and relevant morphometric parameters, such as tendon width and extent of expansions, were measured where feasible using appropriate instruments.

Statistical Analysis

The collected data were analyzed using descriptive statistical methods. The frequency and percentage of different patterns of insertion and observed variations were calculated and presented in tabular form. Morphometric measurements were expressed as mean and standard deviation where applicable. No inferential statistical tests were applied, as the study primarily aimed at anatomical description and pattern analysis.

Results

[Table 1] illustrates the distribution of specimens analyzed in the study, showing a slightly higher proportion of right-sided lower limbs compared to the left.

Table 1: Distribution of Specimens

Parameter	Number (n=50)	Percentage (%)
Right lower limbs	26	52%
Left lower limbs	24	48%

Table 2: Number of Distal Expansions of Semimembranosus

Number of Expansions	Number of Specimens	Percentage (%)
Three (classical)	30	60%
More than three	15	30%
Less than three	5	10%

[Table 2] observes the variation in the number of distal expansions, with the classical three-expansion pattern being the most common.

Table 3: Sites of Distal Attachment

Site of Insertion	Number of Specimens	Percentage (%)
Medial tibial condyle	50	100%
Oblique popliteal ligament	42	84%
Posterior capsule	38	76%
Popliteal fascia	30	60%
Medial meniscus	18	36%

[Table 3] illustrates the various sites of distal attachment of the semimembranosus muscle, with the medial tibial condyle being consistently present in all specimens.

Table 4: Presence of Accessory Slips

Accessory Attachment	Number of Specimens	Percentage (%)
Present	20	40%
Absent	30	60%

[Table 4] shows that accessory slips were present in a significant proportion of specimens, indicating notable anatomical variation.

Table 5: Types of Variations Observed

Type of Variation	Number of Specimens	Percentage (%)
Additional fascial expansion	12	24%
Meniscal attachment	8	16%
Ligamentous extension	10	20%
No variation (classical pattern)	20	40%

[Table 5] observes different types of variations, with additional fascial expansions being the most frequent among variant patterns.

Table 6: Morphometric Measurements (Tendon Width)

Parameter	Mean ± SD
Tendon width at insertion (mm)	12.5 ± 2.3

[Table 6] presents the morphometric analysis of the semimembranosus tendon, showing the average width at the site of insertion.

Table 7: Laterality vs Variation Pattern

Side	Variations Present	Variations Absent
Right (n=26)	12	14
Left (n=24)	8	16

[Table 7] compares the occurrence of variations between right and left lower limbs, with a slightly higher frequency observed on the right side.

Discussion

The present study examined the distal attachment of the semimembranosus muscle in 50 cadaveric lower limbs and documented considerable variability in the number, pattern, and sites of its tendinous expansions. The classical triple expansion pattern was the most frequently observed configuration, present in 60% of specimens, with consistent attachments to the medial tibial condyle, the oblique popliteal ligament (OPL), and the popliteal fascia. This finding is in agreement with Benninger and Delamarter,[6] whose dissection of 56 embalmed cadaver knees demonstrated a consistent trifurcation of the distal semimembranosus muscle–tendon unit (SMTU) into three dominant expansions: one directed obliquely to the posterior joint capsule, a second taking an anterior course with fibres contributing to the medial meniscus and medial collateral ligament before terminating at the anteroinferior medial tibial condyle, and a third descending to the posterior inferior medial tibial condyle with contributions to the popliteus fascia. The trifurcation model of Benninger and Delamarter6 thus closely mirrors the dominant pattern observed in the present series, and their proposal to rename the oblique popliteal ligament as the "oblique popliteal tendon/expansion" to better reflect its origin as an intrinsic continuation of the SMTU deserves consideration in anatomical terminology.

In 30% of specimens, more than three expansions were identified, while 10% showed fewer than three, indicating that the distal semimembranosus cannot be reliably predicted to conform to any single pattern. This degree of variability is well-supported in the literature. Beltran et al,[7] described five distinct tendinous arms of the distal semimembranosus on MRI and cadaveric correlation – the anterior, direct, capsular, inferior, and the OPL arm – noting that these arms intertwine with branches of the posterior oblique ligament (POL) in the posteromedial knee to provide dynamic stability. Sims and Jacobson,[5] similarly enumerated five distal insertions: the pars reflexa, direct posteromedial tibial insertion, OPL insertion, expansion to the posterior oblique ligament, and popliteus aponeurosis expansion. The subset of specimens in the present study with more than three expansions is therefore consistent with this five-arm description, while those with fewer than three likely represent partial agenesis or fusion of individual slips, a phenomenon noted in passing by several authors. A recent morphological classification by Olewnik Ł et al,[8] on 100 lower limbs further proposed three main tendon types – Type I with a single main tendon (66%), Type II with a double tendon (24%), and Type III with three main tendons (10%) – underscoring that variability extends not only to the accessory expansions but to the primary tendon architecture itself.

Regarding specific sites of insertion, the medial tibial condyle was present in all 50 specimens (100%), confirming its role as the primary and constant anchoring point of the semimembranosus at the knee. This is consistent with LaPrade et al,[3] who confirmed the direct arm's consistent attachment to the posterior medial tibial condyle in their detailed anatomical study of the posterior knee. The OPL was present as an insertion site in 84% of specimens, and the posterior capsule in 76%. The high but not universal frequency of both these attachments is consistent with the literature: while most anatomical texts describe the OPL and capsular arm as standard components of the distal SMTU, their occasional absence as independent slips in the present study reflects the morphological continuum in which individual expansions may be fused, attenuated, or absent. The clinical significance of the capsular arm in particular was highlighted by Sims and Jacobson,[3] who reported that 70% of their 93 operatively treated medial knee injuries involved disruption of the semimembranosus capsular attachment, in addition to posterior oblique ligament tears, emphasising that the capsular expansion must be individually assessed and repaired during posteromedial corner surgery.

Attachment to the popliteal fascia was identified in 60% of specimens, and medial meniscal attachment in 36%. The popliteal fascia expansion, often described as the most distal slip of the semimembranosus, has been enumerated by both Sims and Jacobson,[5] and LaPrade et al,[3] as a regular component of the distal SMTU; its presence in only 60% of the current series

suggests it is the most variable of the primary expansions. The meniscal attachment rate of 36% is of particular interest. Kim et al,[9] reported a tendinous branch inserting into the posterior horn of the lateral meniscus in 43.2% of 42 dissected cadaver knees, which is comparable in frequency to the medial meniscal attachment observed in the present study. These meniscal connections are functionally significant because they enable the semimembranosus to dynamically retract the posterior horn of the meniscus during knee flexion, providing protection against meniscal impingement between the femoral condyle and the tibial plateau. From a radiological standpoint, Kim et al,[9] specifically noted that a semimembranosus branch inserting at the posterior meniscal horn may on MRI closely resemble a meniscal tear, making awareness of this variant essential for avoiding misdiagnosis. Benninger and Delamarter,[6] also confirmed fibres from the anterior expansion contributing to the medial meniscus in their trifurcation model, further validating the meniscal arm as a recognised, though variably present, component of the distal semimembranosus.

Accessory slips were present in 40% of specimens overall. Among the specific types, additional fascial expansions were most frequent (24%), followed by ligamentous extensions (20%) and meniscal attachments (16%), while 40% of specimens showed no variation from the classical pattern. Benninger and Delamarter 6 similarly noted considerable variability in the number and configuration of accessory bands in their cadaveric series, as did Olewnik Ł et al,[8] whose novel classification emphasised significant morphometric differences between tendon types that are potentially clinically relevant. The mean tendon width at insertion recorded in the present study was 12.5 ± 2.3 mm. This reflects the divided state of the tendon at its distal end; Olewnik Ł et al,[8] reported a mean width of 38.29 mm measured more proximally on the undivided tendon, which is consistent with the expected progressive narrowing of individual slips as they diverge toward their respective insertion sites.

A slight predominance of variations was observed on the right side (12 of 26 right limbs versus 8 of 24 left limbs), though this difference is modest given the sample size and no formal statistical comparison was made, as the study was descriptive in design. This observation may warrant further exploration in larger series. Overall, the findings of the present study confirm that the distal semimembranosus is an anatomically complex and highly variable structure. As LaPrade et al,[3] emphasised in their comprehensive study of the medial knee, the semimembranosus expansions are integral to posteromedial corner stability, and their precise anatomy must be understood for accurate ligament reconstruction and surgical repair. In radiological practice, the variable insertion pattern documented in the present study reinforces the importance of recognising accessory slips and meniscal connections on MRI so as not to confuse normal anatomical variants with pathology.[7] Awareness of these variations is therefore of direct practical relevance to anatomists, orthopaedic surgeons, and radiologists alike.

Conclusion

The present cadaveric study demonstrates that the distal attachment of the semimembranosus muscle shows considerable anatomical variability, with the classical three-expansion pattern observed in the majority of specimens and a significant proportion exhibiting accessory slips and additional insertions. Consistent attachment to the medial tibial condyle was noted in all specimens, while variable extensions to structures such as the oblique popliteal ligament, posterior capsule, medial meniscus, and popliteal fascia highlight the complex nature of its insertion. These variations underscore the important role of the semimembranosus in maintaining posteromedial knee stability and influencing joint biomechanics. A thorough understanding of these anatomical patterns is essential for orthopedic surgeons and radiologists to improve surgical precision, avoid intraoperative complications, and enhance the accuracy of imaging interpretation.

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Conflicts of interest

There are no conflicts of interest.

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